

## The Effect of Habitual Smoking on $VO_{2max}$

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### Abstract

$VO_{2max}$  is associated with many factors, including age, gender, physical activity, and body composition. It is popularly believed that habitual smoking lowers aerobic fitness. **PURPOSE:** to determine the effect of habitual smoking on  $VO_{2max}$  after controlling for age, gender, activity and BMI.

**METHODS:** 2374 men and 375 women employed at the NASA/Johnson Space Center were measured for  $VO_{2max}$  by indirect calorimetry ( $RER \geq 1.1$ ), activity by the 11 point (0-10) NASA Physical Activity Status Scale (PASS), BMI and smoking pack-yrs (packs·day<sup>-1</sup>·y of smoking). Age was recorded in years and gender was coded as M=1, W=0. Pack y was made a categorical variable consisting of four levels as follows: Never Smoked (0), Light (1-10), Regular (11-20), Heavy (>20). Group differences were verified by ANOVA. General Linear Models (GLM) was used to develop two models to examine the relationship of smoking behavior on  $VO_{2max}$ . GLM #1 (without smoking) determined the combined effects of age, gender, PASS and BMI on  $VO_{2max}$ . GLM #2 (with smoking) determined the added effects of smoking (pack y groupings) on  $VO_{2max}$  after controlling for age, gender, PASS and BMI. Constant errors (CE) were calculated to compare the accuracy of the two models for estimating the  $VO_{2max}$  of the smoking subgroups.

**RESULTS:** ANOVA affirmed the mean  $VO_{2max}$  of each pack y grouping decreased significantly ( $p < 0.01$ ) as the level of smoking exposure increased. GLM #1 showed that age, gender, PASS and BMI were independently related with  $VO_{2max}$  ( $R^2 = 0.642$ ,  $SEE = 4.90$ ,  $p < 0.001$ ). The added pack y variables in GLM #2 were statistically significant ( $R^2$  change = 0.7%,  $p < 0.01$ ). Post hoc analysis showed that compared to "Never Smoked," the effects on  $VO_{2max}$  from Light and Regular smoking habits were  $-0.83$  and  $-0.85$  ml·kg<sup>-1</sup>·min<sup>-1</sup> respectively ( $p < 0.05$ ). The effect of Heavy smoking on  $VO_{2max}$  was  $-2.56$  ml·kg<sup>-1</sup>·min<sup>-1</sup> ( $p < 0.001$ ). The CE's of each smoking group in GLM #2 was smaller than the CE's of the smoking group counterparts in GLM #1.

**CONCLUSIONS:** After accounting for the effects of gender, age, PASS and BMI the effect of habitual smoking on reducing  $VO_{2max}$  is minimal, about  $0.85$  ml·kg<sup>-1</sup>·min<sup>-1</sup>, until the habit exceeds 20 pack y at which point an additional decrease of  $1.71$  ml·kg<sup>-1</sup>·min<sup>-1</sup> is noted. Adding pack y data improves the accuracy of predicting the  $VO_{2max}$  of smokers.

### Introduction

Research shows that  $VO_{2max}$  is related to age, gender, body composition and activity habit, and that the  $VO_{2max}$  of heavy smokers is lower than that of non-smokers. It is not

known how much smoking affects  $VO_{2max}$  after accounting for the effects of these other variables.

## Purpose

To determine the effect of habitual smoking on  $VO_{2max}$  after controlling for the effects of age, gender, activity and BMI.

## Methods

Subjects:

NASA Johnson Space Center, Houston, TX employees  
2374 men, 375 women

Measurements:

$VO_{2max}$  measured by indirect calorimetry

Age – years

Gender – Men = 1, Women = 0

Activity habit by NASA Physical Activity Status Scale (PASS)

Body Mass Index (BMI) = Body weight in kg/Height in meters<sup>2</sup>

Smoking pack-years = packs per day \* years of smoking

Categorical pack-y groupings

Never (0), Light (1-10), Regular (11-20), Heavy (>20)

Statistics:

Analysis of Variance

General Linear Model

## Results

TABLE 1. Descriptive statistics for the 2374 **men** in the sample sorted by pack-yrs.  
(Values are means with standard deviations in parentheses.)

	Pack-year groupings			
	0 (n=1794)	1-10 (n=292)	11-20 (n=150)	>20 (n=138)
Pack yr (pks:day * y of smoking)	0 (0)	4.89 (3.25)	15.82 (2.81)	36.62 (14.09)
$VO_{2max}$ (ml·kg <sup>-1</sup> ·min <sup>-1</sup> )	37.49 (8.27)	35.27 (6.12)	33.46 (6.67)	28.65 (5.53)
RER ( $VO_2/VCO_2$ )	1.25 (0.10)	1.25 (0.09)	1.25 (0.10)	1.23 (0.09)
Age (yr)	48.62 (10.78)	51.91 (9.13)	54.35 (8.41)	58.75 (8.12)
BMI (kg/m <sup>2</sup> )	26.03 (3.32)	26.16 (3.32)	26.64 (2.84)	27.76 (3.65)
PASS (0-10)	5.05 (2.12)	5.01 (2.01)	4.64 (1.98)	4.14 (1.96)

TABLE 2. Descriptive statistics for the 375 **women** in the sample sorted by pack-yrs.  
(Values are means with standard deviations in parentheses)

	Pack-year groupings			
	0 (n=317)	1-10 (n=39)	11-20 (n=9)	>20 (n=10)
Pack yr (pks:day * y of smoking)	0 (0)	4.83 (3.24)	17.28 (3.29)	29.25 (10.91)
$VO_{2max}$ (ml·kg <sup>-1</sup> ·min <sup>-1</sup> )	31.97 (7.72)	32.19 (6.53)	31.91 (5.86)	28.36 (4.72)
RER ( $VO_2/VCO_2$ )	1.23 (0.09)	1.23 (0.09)	1.22 (0.07)	1.21 (0.10)
Age (yr)	42.16 (9.30)	41.26 (8.05)	42.67 (4.39)	48.30 (3.83)

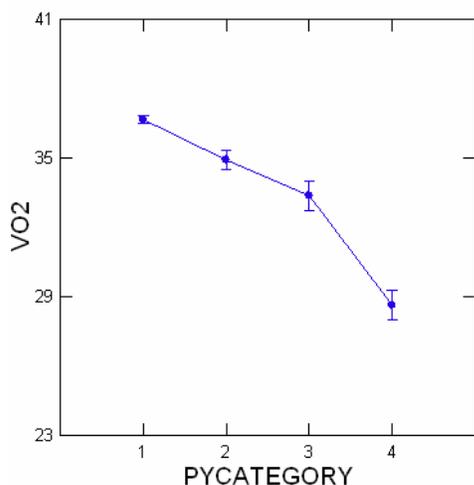
BMI (kg/m <sup>2</sup> )	23.90 (4.07)	23.66 (3.32)	22.70 (5.51)	24.80 (4.14)
PASS (0-10)	4.71 (2.33)	4.77 (2.19)	3.33 (2.45)	3.80 (2.97)

Analysis of Variance shows The effects of smoking on VO<sub>2max</sub> are attenuated by age, gender, activity (PASS) and BMI.

Non-adjusted Pack-yr relationship with VO2max

Difference between “Never” and Heavy”: 8.03 ml·kg<sup>-1</sup>·min<sup>-1</sup> (p<0.001)

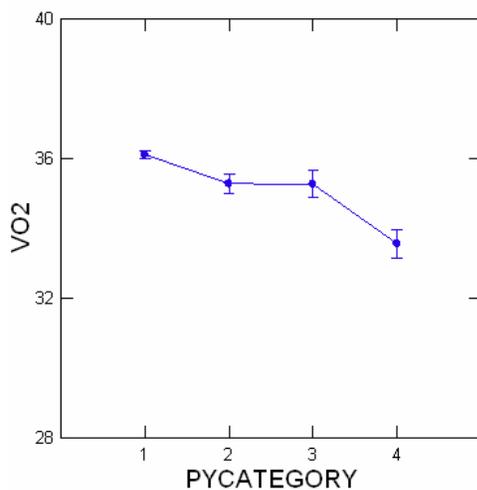
Least Squares Means



Pack-yr/VO2max relationship adjusted for effects of age, gender, PASS and BMI

Difference between “Never” and “Heavy”: 2.56 ml·kg<sup>-1</sup>·min<sup>-1</sup> (p<0.001)

Least Squares Means



## Two General linear models estimate $VO_{2max}$ : without and with smoking

TABLE 3. General linear models estimating  $VO_{2max}$  ( $mL \cdot kg^{-1} \cdot min^{-1}$ )

	Model 1 Without Smoking	Model 2 With Smoking
Constant	57.402*	56.690*
Age (yr)	-0.372*	-0.358*
Gender (M = 1, F = 0)	8.596*	8.582*
PASS (0-10)	1.396*	1.392*
BMI	-0.683*	-0.669*
Light (1-10 Pack-yrs)		-0.833**
Moderate (11-20 Pack-yrs)		-0.852**
Heavy (>20 Pack-yrs)		-2.556*
R	0.802*	0.805*
R <sup>2</sup>	0.642*	0.649*
SEE	4.900*	4.858*

\*P<0.0001; \*\*P<0.05

Constant errors for smoking subgroups show the “with smoking” model reduces errors in estimating  $VO_{2max}$  for smokers.

TABLE 4. Measured and estimated  $VO_{2max}$  sorted according to pack-yr grouping. (Constant errors (CE) with standard deviations (SD) are shown for subgroup estimates by Models 1 and 2.).

Pack-yr Groups	Measured		Model 1				Model 2			
	Mean	SD	Mean	SD	CE	SD	Mean	SD	CE	SD
Never (n=2109)	36.66	8.42	36.39	6.75	0.27	4.99	36.68	8.67	-0.02	5.00
Light (n=331)	34.91	6.24	35.43	5.37	-0.52	4.23	34.93	6.38	-0.02	4.22
Moderate (n=159)	33.37	6.62	33.86	5.04	-0.49	4.65	33.39	6.02	-0.02	4.66
Heavy (n=148)	28.63	5.46	30.74	5.05	-2.12	4.27	28.64	5.17	-0.02	4.25

Means are for  $VO_{2max}$  ( $mL \cdot kg^{-1} \cdot min^{-1}$ ); SD are standard deviations for the means and standard error of estimates for the CE of each subgroup;  $CE = \sum(\text{measured } VO_{2max} - \text{estimated } VO_{2max})/n$

### Conclusion

- After accounting for the effects of age, gender, PASS and BMI the effect of habitual smoking on  $VO_{2max}$  is minimal, about  $0.85 mL \cdot kg^{-1} \cdot min^{-1}$ , until the habit exceeds 20 pack-yrs at which point an additional decrease of  $1.71 mL \cdot kg^{-1} \cdot min^{-1}$  is noted.
- The addition of smoking to the prediction of  $VO_{2max}$  lowers prediction error, especially for heavy smokers.